nances at $E_x=19$ and 22 MeV in the inelastic scattering of protons from C^{12}, and the former resonance has been identified[3] with the missing 2^-, $T=1$ state and the latter with the main 1^-, $T=1$ state. In a detailed calculation, Sanderson[32] has shown that the observed angular distributions of the inelastic protons are consistent with attributing the lower resonance to the group of predicted levels in the range 18 MeV$<E_x<$20 MeV and the upper resonance to the group in the region 22 MeV$<E_x<$24 MeV. The main contributions to the two resonances arise from the 2, $T=1$ and 1^-, $T=1$ states, respectively. The recent work of Walecka and deForest[23] would confirm the presence of the 2^-, $T=1$ state.

[32] E. A. Sanderson, Nucl. Phys. **35**, 557 (1962).

ACKNOWLEDGMENTS

We would like to acknowledge conversations with Dr. W. C. Barber and Dr. J. D. Walecka on the recent status and interpretations of electron-scattering experiments on C^{12}. Thanks are also due to Dr. H. R. Blieden and Dr. H. W. Koch for sending us data prior to publication and to David Hanna for his assistance in analyzing the data.

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(p,t) Ground-State $L=0$ Transitions in the Even Isotopes of Sn and Cd at 40 MeV, $N=62$ to 74*

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(Received 29 March 1965)

The (p,t) reaction has been used to investigate the ground-state $L=0$ transitions in the seven even Sn isotopes and four even Cd isotopes with the University of Minnesota Linear Accelerator 40-MeV proton beam. Angular distributions have been taken in the range 7° to 25° in most cases, and the integrated cross sections used for comparison with the theory. The isotopes of Sn have a closed $Z=50$ proton shell and should be rather well described in terms of the neutrons outside of the $N=50$ shell. The detailed description of the neutron configurations is available from theoretical work and one-neutron transfer reactions. The agreement between pairing spectroscopic factors and the experimental cross sections is not good. It is clear that a distorted-wave Born-approximation analysis of the data is necessary, as well as, perhaps, a better understanding of the nuclear structure of the Sn isotopes. The Cd data show that an open proton shell decreases the number of $J=0$ coupled neutron pairs in the ground state.

I. INTRODUCTION

THE importance of the (p,t) reaction as a means of investigating certain properties of nuclear states has been demonstrated recently.[1] In particular the study of the (p,t) reaction can yield very useful information concerning the description of the neutron configuration in terms of correlated neutron pairs.

The even isotopes of tin are particularly interesting for a systematic study with the (p,t) reaction for several reasons. The 50 protons complete the filling of a major shell and should not be excited in the two-neutron pickup reaction. In addition, the low-lying states in these nuclei should be described quite well in terms of a mixed configuration of neutrons outside of the major closed shell of 50. A rather detailed description of the neutron configurations in these nuclei is available from theoretical calculations and one-neutron transfer reactions. This paper contains the results of an investigation of the (p,t) reaction on the seven even isotopes of tin and four even isotopes of cadmium using the 40-MeV proton beam of the University of Minnesota Linear Accelerator. Particular emphasis is placed on the ground-state transitions. The cadmium isotopes were studied in order to determine the effects of the nonclosed proton shell on the neutron configuration by comparison with the corresponding isotopes of tin.

In general the L value, that is the total orbital angular momentum for the transferred neutron pair, can be obtained from the shape of the angular distribution of the outgoing tritons. To the extent that the two neutrons in the triton are in a relative space-symmetric $S=0$ state, which is about 95% of the time,[2] $L=J$ (where $\mathbf{J}=\mathbf{L}+\mathbf{S}$) for the transferred neutron pair and the selection rule $|J_i-J_f|\leqq L\leqq(J_i+J_f)$ holds for the reaction. In the case of even-even targets these rules reduce to $L=J=J_f$. In addition, the selection rule $\Delta\pi=(-1)^L$ is valid in the approximation that the triton

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[1] G. Bassani, Norton M. Hintz, and C. D. Kavaloski, Phys. Rev. **136**, B1006 (1964).
[2] J. M. Blatt, G. H. Derrick, and J. N. Lyness, Phys. Rev. Letters **8**, 323 (1962).

wave function contains only relative s-state motion between the neutrons. A complete discussion of selection rules is contained in Ref. 1.

For the (p,t) ground-state transitions on the even isotopes of tin and cadmium one expects only $L=0$ for the picked-up neutron pair. The angular distributions for $L=0$ transitions have been observed for the (p,t) ground-state transition for many nuclei and are very similar over a wide range of Z and A.[1] The $L=0$ and $L=2$ angular distributions are easily differentiated.

The sum of the $L=0$ transition strengths to the various states of a particular nucleus is a measure of the number of neutron pairs coupled to $J=0$ in the target ground state. The configuration mixing in the neutron wave function produced by a pairing interaction is such that the pair correlation in the ground state is increased so as to increase the number of $J=0$ coupled pairs. In the calculation of the amplitude for the (p,t) reaction all of the contributions from the various configurations have the same sign and add coherently so that the strength of the ground-state $L=0$ transition is enhanced at the expense of the other $L=0$ transitions which are expected at higher excitation. In previous work no appreciable $L=0$ strength ($\geqq 10\%$ of the ground-state transition strength) has been observed in excited-state transitions below about 4–5 MeV,[1] which seems to confirm the importance of the pairing force component in the nucleon-nucleon interaction.

The results of an approximate calculation indicate that the $L=2$ transition strength may not be concentrated in one particular state,[3] and indeed several strong $L=2$ transitions are observed in the tin energy spectra. The study of the $J=2$ coupled neutron pairs (related to the $L=2$ transition strengths) then presents several difficulties. Since the $L=2$ strength is distributed over several MeV of excitation, it is necessary to have better energy resolution than is presently available. Also, targets of higher isotopic enrichment are required than for the study of ground-state transitions. Thus we have no information for higher L transitions at the present time.

II. EXPERIMENTAL METHOD

The instrumentation used for this investigation has been described previously.[1] Briefly, tritons are selected with the University of Minnesota 40-in., 180° magnetic spectrometer and detected with an array of 8 plastic scintillators $\frac{1}{16}$ in. thick mounted at the focal plane. The resolution of the system is about 2% and limited almost entirely by the height of the counters in the focal plane. The detectors are stopping counters for tritons up to an energy of about 20 MeV. The outputs of the 8 detectors are analyzed in eight, 32-channel, subgroups of a Nuclear-Data 1024-channel pulse-height analyzer.

For particles with the same energy, tritons have the highest magnetic rigidity, and deuterons the next highest. Although the Q values for the (p,t) reactions are generally more negative than for (p,d), the difference in rigidity allows triton energy spectra to be taken up to several MeV of excitation without encountering deuteron groups.

The isotopic targets used in this experiment were either metallic foil targets[4] or oxide powder targets in a binder of polystyrene. Data were taken for $Sn^{116,120}$ and Cd^{116} using both kinds of targets. Particular care has been taken in the determination of the target thickness. The uncertainty in the absolute normalization of the differential cross-section data is estimated to be less than 30%. The relative errors in the integrated cross-section data are due primarily to uncertainties in the target thickness measurements and counting statistics and are estimated to be less than 10% for the data taken with the foil targets and 15% for the data taken with the oxide powder targets.

Foil Targets

Foil targets of $Sn^{112,114,116,120,122,124}$ and Cd^{116} were used for the investigation. Target thickness measurements were made by (a) determining the areal density from an accurate measurement of the area and weight of the foil, (b) measuring the energy loss of α particles in the foil, and (c) analyzing elastic-scattering data for a few of them. Agreement is within 7% in all cases.

Oxide Powder Targets

Data have been taken using oxide powder[5] targets of $Sn^{116,118,120}$ and $Cd^{110,112,114,116}$. These targets are generally quite fragile and for safe handling they were sandwiched between two $\frac{1}{2}$-mil polyethylene sheets. The method of preparing these targets has been described elsewhere.[6] These targets are particularly suitable for (p,t) studies for several reasons. Carbon is present in the chemical form of polystyrene and polyethylene, but the $C^{12}(p,t)C^{10}$ ground-state Q value is -23.3 MeV.[7] Oxygen is present due to the oxide form of the target material, but the $O^{16}(p,t)O^{14}$ Q value is -20.4 MeV. The Q values for the ground-state reactions for the isotopes of Sn and Cd are in the range -6 to -10 MeV, so that the carbon and oxygen triton groups appear at a very high excitation in these spectra. Further, the poylstyrene and polyethylene contain no oxygen. This is convenient because

[3] S. Yoshida, Nucl. Phys. **33**, 685 (1962).

[4] Loaned to us by the University of Pittsburgh through the courtesy of B. L. Cohen.

[5] Obtained from Isotopes Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[6] G. Bassani, Norton M. Hintz, J. R. Maxwell, and Glenn M. Reynolds, University of Minnesota Linear Accelerator Laboratory Progress Report, 1964 (unpublished).

[7] The Q values used in this work were taken from the Nucl. Data Tables, U. S. At. Energy Comm. 1960; the energies and spins of known excited states were taken from *Landolt-Börnstein Tables*, edited by K. H. Hellwege (Springer-Verlag, Berlin, 1961), Vol. 1.

the oxygen in the oxide powders of Sn and Cd provides a useful way of finding the target thickness.

The target thickness for the oxide targets was obtained by measuring the yield of deuterons from the $O^{16}(p,d)O^{15}$ ground-state reaction from the oxygen in the target and comparing with the $O^{16}(p,d)O^{15}$ ground-state cross section determined from the oxygen in a $\frac{1}{4}$-mil Mylar sheet. This is a good method in that the (p,t) and $O^{16}(p,d)O^{15}$ measurements are made with the beam hitting the same target area so that the measurements are quite independent of the uniformity of the target. The $O^{16}(p,d)O^{15}$ ground-state Q value is -13.4 MeV and occurs at 4–6 MeV of excitation in the (p,d) spectrum of the isotope in the target. The levels at this excitation are generally rather weakly excited compared to the $O^{16}(p,d)O^{15}$ ground state, but the possibility exists that one of these levels is strongly excited and lies under the deuteron group. However, the measurements have been made at 10°, 15°, and 20° in order to check that a level with an angular distribution different from that of the $O^{16}(p,d)O^{15}$ is not hidden under the oxygen deuteron group.

As an additional check on the oxide target measurements, the (p,t) ground-state differential cross-section data taken with the SnO_2 targets of Sn^{116} and Sn^{120} as well as a CdO target of Cd^{116} were compared with data from the corresponding foil targets. The agreement is quite good for the Sn^{120} and Cd^{116} data. The Sn^{116} data taken with the oxide target are about 20% low.

The thickness of the SnO_2 targets was also measured by burning out all of the carbon and hydrogen from a piece of the target $\frac{1}{4}$ in. in diameter and then weighing the dry residue. For each SnO_2 target, the two methods for measuring thickness were in agreement to within 10%.

III. RESULTS

The angular distribution for the $Sn^{120}(p,t)Sn^{118}$ ground-state $L=0$ transition is shown in Fig. 1 from

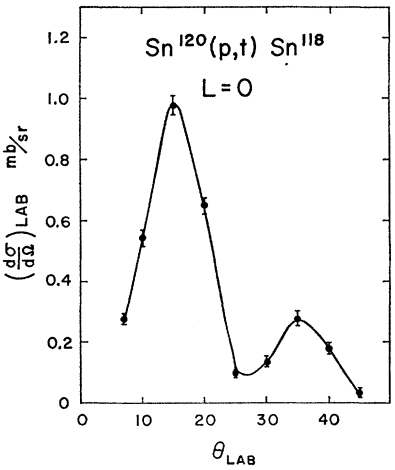

FIG. 1. Angular distribution of tritons from $Sn^{120}(p,t)Sn^{118}$, ground state.

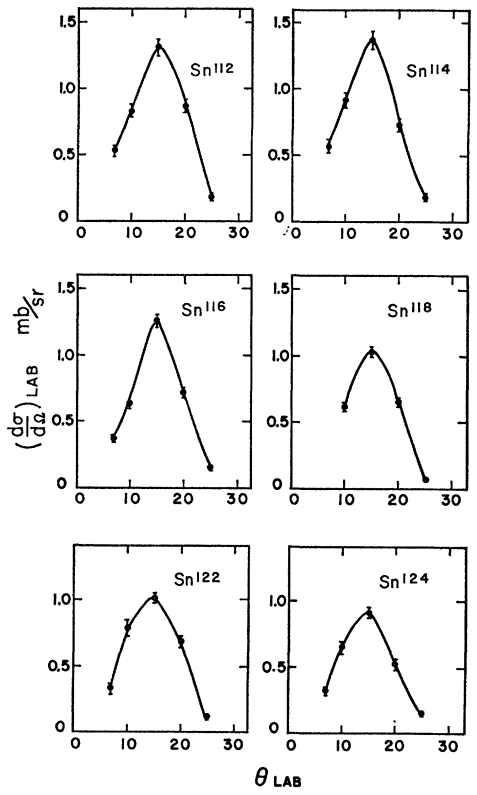

FIG. 2. Angular distributions of tritons from even Sn isotopes, ground states.

7° to 45°. The error bars indicate counting statistics only. The general features of this angular distribution are very similar to those observed for the ground-state angular distributions for nuclei in the Ti-to-Zn region[1] except that the maximum in the angular distribution has moved in from about 20° to about 15°. Ground-state angular distributions for the other even Sn and Cd isotopes are shown in Figs. 2 and 3. All of the ground-state angular distributions are very similar. In the process of extracting a "relative empirical spectroscopic factor," the cross sections are integrated only over the first maximun so that the angular distributions have not, in general, been extended beyond 25°. Cross sections for angles less than 7° have not been measured because of the limitation imposed by the size of the Faraday cup.

The $Sn^{120}(p,t)Sn^{118}$ angular distribution for the $L=2$ transition to the 2^+ first excited state in Sn^{118} is shown in Fig. 4. This angular distribution is similar to those to 2^+ states for the nuclei in the Ti-to-Zn region also.

The energy spectra at 7° and 15° for the reaction $Sn^{120}(p,t)Sn^{118}$ are shown in Fig. 5. Excitation energies are shown on the figure. The $L=0$ transitions are easily recognized because the maximum in the cross section occurs at 15° with a minimum at 7°. The $L=2$ transitions, on the other hand, peak at 7°. The errors in excitation energies are estimated to be less than about 200 keV. The ground-state transition appears to be the

only strongly excited $L=0$ transition in the spectrum. The cross section for the first excited 2^+ state at 1.22 MeV in Sn^{118} is stronger at 7° than at 15°, and there are several states higher up in the spectrum which are probably $L=2$ transitions as judged from the ratio of the cross sections at 7° and 15°. It appears that none of the higher states correspond to $L=0$ transitions with appreciable strength relative to the ground-state transition.

IV. DISCUSSION OF THE $L=0$ DATA

A complete discussion of spectroscopic factors and distorted-wave Born-approximation (DWBA) equations for the (p,t) reaction has been presented elsewhere[1]; only a few pertinent points will be mentioned here. If one assumes that the reaction proceeds via a direct one-step

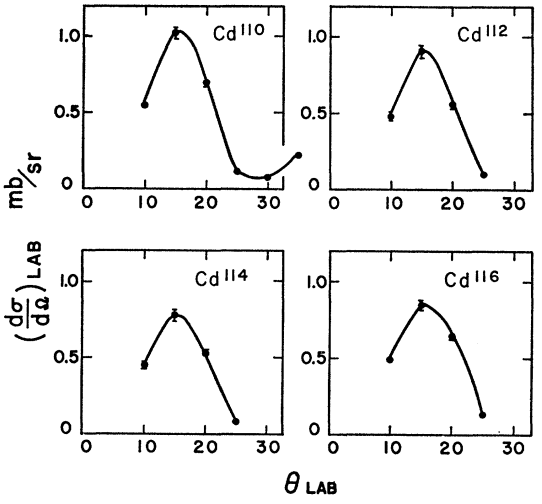

FIG. 3. Angular distributions of tritons from even Cd isotopes, ground states.

mechanism and that $L=J$ for the transferred neutron pair, the cross section for the reaction can be written in the form

$$d\sigma/d\Omega=\sum_L\Big|\sum_{l_1j_1l_2j_2}[S_L(l_1j_1l_2j_2)]^{1/2}\times[G_L(\theta k_ik_fl_1j_1l_2j_2)]^{1/2}\Big|^2. \quad (1)$$

The $[S_L(l_1j_1l_2j_2)]^{1/2}$ is a spectroscopic amplitude, where $S_L(l_1j_1l_2j_2)$ is the probability of finding in the target-nucleus ground state a given state of the residual nucleus plus two neutrons in states l_1, j_1 and l_2, j_2 coupled to angular momentum L. The quantity $G_L(\theta k_ik_fl_1j_1l_2j_2)$ in general depends on nuclear-structure factors only through a dependence in the single-particle neutron wave functions. The cross section is given by a coherent sum corresponding to the pickup of a pair of neutrons in various single-particle orbits.

In the case of a pure configuration, where the two picked-up neutrons are in definite orbits l_1, j_1 and l_2, j_2

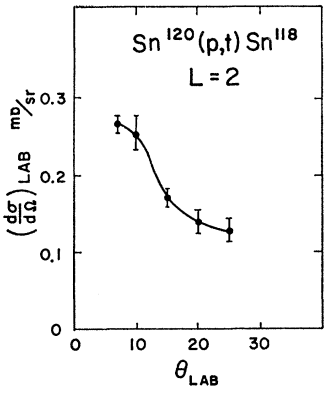

FIG. 4. Angular distributions of tritons from $Sn^{120}(p,t)$-Sn^{118}, 1.22-MeV state.

the cross section reduces to an incoherent sum of the form

$$d\sigma/d\Omega=\sum_L S_L(l_1j_1l_2j_2)G_L(\theta k_ik_fl_1j_1l_2j_2), \quad (2)$$

where the S_L is then a true spectroscopic factor.

Yoshida has shown that the ground-state transition cross section can be written in the pairing force approximation, using a plane-wave theory, as[3]

$$d\sigma/d\Omega\propto j_0^2(QR)\,|\textstyle\sum_j(2j+1)U_j^fV_j^i|^2. \quad (3)$$

An approximate expression for the radial integrals [which are included in the factors G_L in Eq. (1)] has been used, but the pairing force approximation should be good for the Sn isotopes with a closed shell of protons. The U_j's and V_j's are the occupation amplitudes for the states l, j in the pairing theory and are defined in Ref. 8. The second factor, $|\sum_j(2j+1)U_j^fV_j^i|^2$ in Eq. (3) will be referred to as the "pairing spectroscopic factor."

In the pairing-force approximation it is interesting to note that the contributions to the ground-state cross

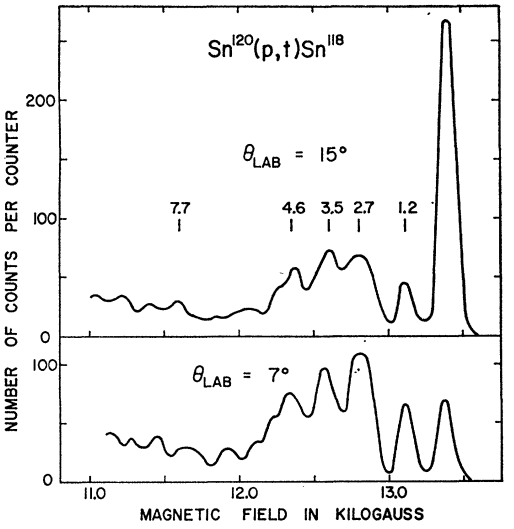

FIG. 5. Energy spectra of tritons from $Sn^{120}(p,t)Sn^{118}$.

[8] S. Yoshida, Nucl. Phys. 38, 380 (1962).

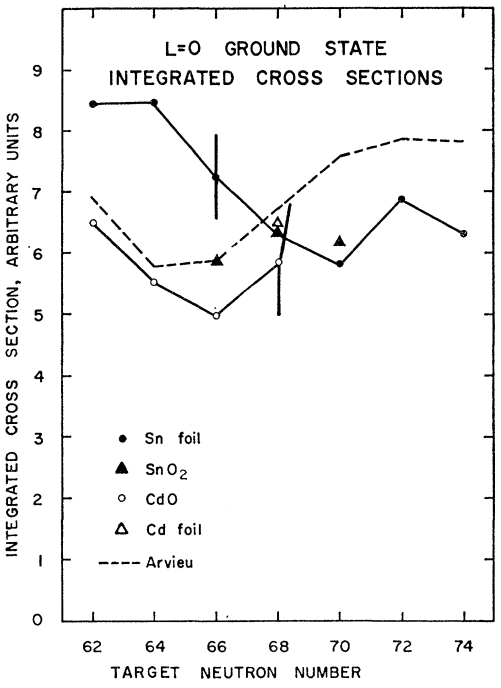

FIG. 6. Ground-state, $L=0$, integrated cross sections for even Sn and Cd isotopes. Relative errors are $\pm 10\%$ on data taken with foil targets, and $\pm 15\%$ on data taken with oxide powder targets. The dashed line gives the predicted values using U_j's and V_j's of Arvieu.

section from the various neutron orbitals all add coherently so that most of the transition strength is expected to be found in the ground state. This is in fact exhibited in the $Sn^{120}(p,t)Sn^{118}$ spectrum and has been observed on nuclei in the Ti-Zn region.[1]

Distorted-wave fits to the data have not yet been made, so in order to compare the data with the predictions of the theory the cross sections measured in the laboratory have been integrated over the first maximum in the angular distribution according to

$$S=\sum_{10^\circ}^{25^\circ}(d\sigma/d\Omega)\sin\theta. \qquad (4)$$

These integrated cross sections, or "relative empirical spectroscopic factors," are then compared with the "pairing spectroscopic factors" of Eq. (3). This is very nearly the same as comparing the maximum cross sections in the angular distributions or as comparing the areas under the peaks because of the similarity in the shape of the angular distributions. The method of comparing cross sections to interpret the data has been used successfully for nuclei in the $2p$-$1f$ shell.[1]

The "relative empirical spectroscopic factors" for the ground-state transitions in the even isotopes of Sn and Cd are shown in Fig. 6. Error bars of $\pm 10\%$ are assumed for data taken with the foil targets and $\pm 15\%$ for data taken with the oxide targets and are due almost entirely to uncertainty in target thickness measurements.

Kisslinger and Sorensen have calculated the occupation amplitudes (the U_j's and V_j's) for the Sn isotopes using a pairing force,[9] and Arvieu has performed the calculations using a more realistic two-body force.[10] The "pairing spectroscopic factors," $|\sum_j(2j+1)U_j^fV_j^i|^2$ using the U_j's and V_j's of Arvieu are shown by the dashed line in Fig. 6, arbitrarily normalized to the data, and are not very different from the predictions using the U_j's and V_j's of Kisslinger and Sorensen.

Cohen and Price have determined the U_j's and V_j's for the Sn isotopes from single-neutron-transfer reactions.[11] The predicted "pairing spectroscopic factors" using their U_j's and V_j's are similar to those of Arvieu for Sn^{116} to Sn^{124}. With Cohen's U_j's and V_j's, the $Sn^{114}(p,t)Sn^{112}$ ground-state transition is predicted to be much larger than the $Sn^{116}(p,t)Sn^{114}$ transition. They find the $1h_{11/2}$ orbit in Sn^{112} to be completely empty so that a discontinuity is introduced into the occupation amplitude of this orbit. This is not too surprising in view of the difficulty of measuring the occupation amplitude by one-nucleon stripping reactions for orbits that are almost empty, and particularly those involving $l_n=5$ transitions.

In general the integrated cross sections for the lighter Sn isotopes are larger than those for the heavier isotopes, in contrast to what is predicted by the theory, and the over-all agreement with the theory is seen to be not very good. It may be that the approximate expression for the radial integrals in the Yoshida formula Eq. (3) is not sufficiently good. In the pairing force approximation the spectroscopic amplitude $[S_L(l_1j_1l_2j_2)]^{1/2}$ in Eq. (1) is proportional to $(2j+1)^{1/2}U_j^fV_j^i$; the other $(2j+1)^{1/2}$ arises from the approximate expression for the radial integrals. The contributions of $(2j+1)U_j^fV_j^i$ to the pairing spectroscopic factor of the various neutron orbits are given in Table I. The importance of the pickup from orbits with large j, particularly the $1h_{11/2}$ and $1g_{7/2}$ orbits, is evident. However, the trend toward larger pairing spectroscopic factors for the heavier Sn isotopes is very persistent and remains even with the $(2j+1)^{1/2}$

TABLE I. Contributions of $(2j+1)U_j^fV_j^i$ to the pairing spectroscopic factors from each neutron orbit. The U_j's and V_j's have been taken from Ref. 10. For Sn^{110} the U_j's are values extrapolated from the U_j's of the other Sn isotopes.

Target	Sn^{112}	Sn^{114}	Sn^{116}	Sn^{118}	Sn^{120}	Sn^{122}	Sn^{124}
Orbit							
$2d_{5/2}$	2.96	2.34	1.67	1.39	1.31	1.22	1.11
$1g_{7/2}$	4.91	3.58	2.40	1.69	1.46	1.29	1.14
$3s_{1/2}$	0.74	0.95	1.17	1.14	1.06	0.96	0.85
$2d_{3/2}$	0.86	0.99	1.38	1.74	1.99	2.15	2.22
$1h_{11/2}$	1.84	2.34	3.81	5.15	6.00	6.47	6.66

[9] L. S. Kisslinger and R. A. Sorensen, Kgl. Danske Videnskab. Selskab, Mat. Fys. Medd. **32**, No. 9 (1960).

[10] R. Arvieu, Ph.D. thesis, Faculté des Sciences de l'Université de Paris (unpublished).

[11] B. L. Cohen and R. E. Price, Phys. Rev. **121**, 1441 (1961); and R. E. Price, Ph.D. thesis, University of Pittsburgh, 1962 (unpublished).

factor replaced by a constant (constant radial matrix element approximation).

It is clear that a distorted-wave treatment of the data is required using realistic bound-state wave functions. The Q-value effect of the cross sections must also be considered in a correct treatment of the data. As the neutron number in the sequence of Sn isotopes increases, the neutrons become less bound and the Q values less negative. If the (p,t) reaction occurs at the nuclear surface, this effect would tend to increase the pickup cross section in the heavier isotopes. That is, if included in the predicted "pairing spectroscopic factors" shown in Fig. 6, the effect would tend to make the discrepancy even larger. It is not clear, however, just how the binding energies should be treated in the DWBA analysis.

The disagreement between the experiment and theory may, however, be due to the assumed configuration of neutrons in the Sn isotopes. The U_j's and V_j's that have been used involve only the neutrons outside the closed-shell core of 50 protons and neutrons. However, for the lighter Sn isotopes it may be necessary to include the effect of some excitation of the closed neutron shells in the ground states. Presumably this effect will be less pronounced for the heavier isotopes. This effect would increase the cross sections predicted for the lighter Sn isotopes and account for some of the discrepancy between the theory and the data. A similar discrepancy with pairing theory has been seen for the Ni isotopes.[1]

The Cd $L=0$ integrated cross sections shown in Fig. 6 are smaller than for the corresponding Sn isotopes, as might be expected. The effect of opening the closed proton shell would tend to introduce components into the wave functions with neutron and proton spins not separately zero, thus decreasing the number of $J=0$ coupled neutron pairs and hence the $L=0$ cross sections. A similar effect has already been observed in comparing the Fe isotopes to the Ni isotopes.[1] The apparent agreement of the Cd data with the theoretical curve for Sn is probably coincidental.

Note added in proof. In order to check the relative-target-thickness measurements, the elastic scattering yield of 40-MeV protons from Cd in the four CdO targets has recently been measured over the peak in the angular distribution near 50°. The relative spectroscopic factors shown in Fig. 6 were not changed by more than the 15% errors on the data.

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Measurement and Statistical Theory Analysis of $Fe^{56}(He^3,p)$ and $Cu^{63}(He^3,p)$ Energy and Angular Distributions–Nuclear Shell Effects*

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(Received 13 April 1965)

Thin Fe^{56} and Cu^{63} targets (approximately 1.5 mg/cm²) were bombarded with 10-MeV He^3 particles. The proton energy and angular distributions produced by the $Fe^{56}(He^3,p)$ and $Cu^{63}(He^3,p)$ reactions were measured by the $E-\Delta E$ particle identification technique. In the statistical theory interpretation of the experimental cross sections both the shape and magnitude of the angular and energy distributions were calculated. Contributions from the (He^3,np) and $(He^3,2p)$ reactions were also calculated. Large sections of the measured proton energy and angular distributions (about 90% of the total cross sections) are consistent with the predictions of the statistical theory of compound-nucleus reactions. A conventional statistical theory calculation of the $Cu^{63}(He^3,p)$ cross sections is generally consistent with the experimental cross sections; however, a similar conventional calculation of the $Fe^{56}(He^3,p)$ cross sections yields values 50% smaller than the experimental results. Rosenzweig has derived an expression for nuclear level densities which indicates that level densities of nuclei in the immediate vicinity of the doubly closed shell Ni^{56} nucleus can be influenced by nuclear shell structure at excitation energies as high as 15 MeV. A second statistical theory calculation of the magnitude and shape of the $Fe^{56}(He^3,p)$ cross sections, based on the Rosenzweig level density expression, yields calculated cross sections generally consistent with the measured $Fe^{56}(He^3,p)$ cross sections.

I. INTRODUCTION

IN this paper we describe the measurement of proton energy and angular distributions produced by bombarding Fe^{56} and Cu^{63} targets with 10-MeV He^3 ions, and present a statistical theory analysis of those portions of the cross-section measurements which are consistent with statistical theory. We were interested in determining the magnitude of the compound-nucleus contribution to these reactions, in the possibility of using (He^3,p) compound-nucleus reactions to obtain information about nuclear level densities, and in the

* Work supported by the U. S. Atomic Energy Commission.
† Part of this work was done in conjunction with another study as partial fulfillment of the Ph.D. requirement at the University of Rochester. Now on active duty in Armée de la République Française. Permanent address: 146 Rue de Tocqueville, Paris 17e, France.

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